Chapter 5

Teeth

The upper and lower jaws are dermal bones with a fascinating evolutionary history. Teeth in the upper and lower jaws appear to have evolved from fish scales. The living core of a mammalian tooth is a dense bone-like material called **dentin**, or **dentine**, a special type of calcified but slightly resilient connective tissue that extends into a socket in the jaw. The crown of the tooth is covered with a layer of extremely hard, brittle material known as **enamel**. These basic tissues have been molded by evolution into an impressive variety of shapes and sizes among the vertebrates.

Teeth are some of the most important parts of human anatomy for the osteologist. Teeth owe their importance in paleontology and anthropology to a variety of factors. Of all the skeletal elements, teeth are the most resistant to chemical and physical destruction. They are, therefore, overrepresented relative to other parts of the skeleton in almost all archaeological and paleontological assemblages. In addition to being abundant, teeth constitute a focus of anthropological and paleontological interest because they are so informative about the individual who possessed them. Teeth provide information on the age, sex, health, diet, and evolutionary relationships of extant and extinct mammals, hominids included.

Teeth are formed deep within the jaws and then erupt through the gum tissue once nearly complete. Unlike the changing shapes of other skeletal elements, tooth crown morphology can only be altered by **attrition** (tooth wear), breakage, cultural modification (*e.g.,* tooth filing), or demineralization once the crown erupts. Tooth morphology can be used to effectively differentiate between populations within a species, species within a genus, and so forth. The stability and adaptive significance of dental form establish teeth as a centerpiece in many comparative populational and evolutionary studies. Finally, teeth are the only hard tissues of the body that are directly observable without dissection or radiography.

Dental measurement and terminology are discussed in Chapter 2. Dental pathology is reviewed in Chapter 19. The use of teeth in sexing and aging is discussed in Chapter 18. The use of dental traits in estimating population distance is covered in Chapter 21. The principles of identification discussed in this chapter form the foundation upon which all other aspects of dental studies are based.

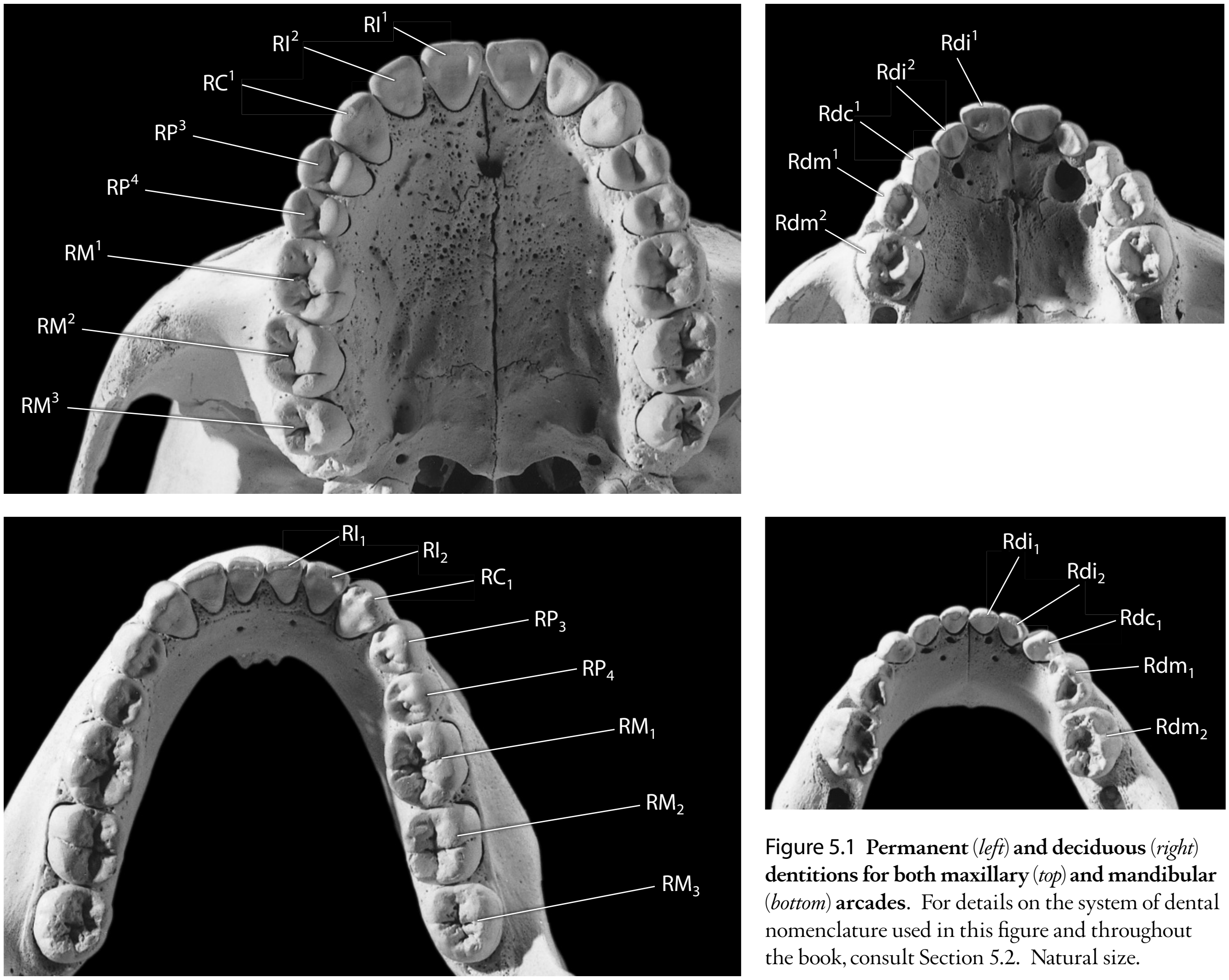


Figure 5.1 **Permanent** (*left*) **and deciduous** (*right*) **dentitions for both maxillary** (*top*) **and mandibular** (*bottom*) **arcades.** For details on the system of dental nomenclature used in this figure and throughout the book, consult Section 5.2. Natural size.

5.1 Dental Form and Function

Teeth constitute the only part of the skeleton that interacts directly with the environment, serving to seize and **masticate** (chew) food. Both the internal composition and the external morphology of teeth are adapted to this primary function in considerable detail among mammals. The particular functions played by specific tooth categories in mammals vary by taxa, but in general, incisors serve primarily to nip or bite food into manageable pieces, canines serve to grasp and capture prey, and premolars and molars serve to chop or crush these pieces further before swallowing.

In adult hominids (Figure 5.1), **incisors** are the eight spatulate teeth in the front of the upper and lower jaws (four in each jaw, two on the right and two on the left). Unworn incisors display sharp, thin cutting edges. Modern human canines function primarily as posterior extensions of the incisor rows, but they retain a more conical shape than the incisors. Human **premolars** are termed "bicuspids" by dentists. In humans there are four premolars in the upper jaw and four in the lower jaw. **Molars** make up the remainder of the human tooth row. Molars are the largest teeth; their extensive chewing surfaces emphasize crushing and grinding rather than biting and shearing. There are usually six molars in both upper and lower adult human jaws.

Humans have retained the primitive mammalian pattern of having two successive sets of teeth. The **deciduous** (**primary** or '**milk**') dentition is the first set of teeth to form, erupt, and function in the first years of life. These teeth are systematically shed and replaced by their counterparts in the **permanent** (**secondary**) dentition throughout childhood and adolescence.

5.2 Dental Terminology

Section 2.2.2 identifies some directional terms specific to teeth. Because work on dental anatomy makes extensive use of these terms, a brief review is essential here. In dental anatomy, the **mesial** portion of the tooth is closest to the point where the central incisors contact each other, and **distal** is the opposite of mesial (Figure 5.3). The **lingual** part of the tooth crown is toward the tongue. **Labial** is the opposite of lingual but is usually reserved for the incisors and canines. **Buccal** is also the opposite of lingual but is usually reserved for the premolars and molars, where the term refers to that part of the tooth that lies toward the cheeks. **Interproximal** tooth surfaces contact adjacent teeth, and the chewing surface of the tooth is the **occlusal surface**. The tooth roots are suspended in **sockets** (**alveoli**) in the mandible and maxillae by periodontal ligaments.

To fully identify a tooth, five variables must be specifically reported: category of tooth, permanent or deciduous dentition, upper or lower arcade, position within the tooth category series, and side.

a. Tooth **category** indicates whether the tooth is an incisor, canine, premolar, or molar. Study of the teeth is considerably simplified through the use of a conventional shorthand that unambiguously identifies each tooth. In this shorthand, **I** indicates an incisor, **C** indicates a canine, **P** indicates a premolar, and **M** indicates a molar.

b. **Dentition** indicates to which of the two successive sets of teeth the tooth belongs: the deciduous dentition or the permanent dentition. When **I**, **C**, **P**, or **M** are capitalized, the tooth is understood to be from the permanent dentition. When **i**, **c**, or **m** are shown in lowercase and preceded by the letter **d**, they denote deciduous incisors, canines, and molars. Because the deciduous molars are replaced by permanent premolars, paleontologists usually refer to these teeth as deciduous premolars. Thus the paleontological abbreviation **dp** is the equivalent of the anthropological **dm**.

c. The **positions** of all teeth are indicated by numbers, indicating the relative position that the tooth holds among teeth of the same category in the tooth row. The numeric positions for each category of tooth increase distally, beginning at 1, the number assigned to the tooth in the mesialmost position. To make comparisons of homologous teeth easier between mammalian species, scientists have traditionally numbered each position according to its location in the primitive mammalian tooth row. Primitive mammals had 3 incisors, 1 canine, 4 premolars, and 3 molars in both arcades (abbreviated with the **dental formula** $\frac{3:1:4:3}{3:1:4:3}$). Through the course of evolution, humans (as well as apes and Old World monkeys) have lost the primitive third incisor and the first two primitive premolars (our dental formula is $\frac{2:1:2:3}{2:1:2:3}$). Thus human incisors are numbered either **1** or **2** (for central or lateral incisors, respectively). Human canines are all **1**s. Because humans have lost the first two primitive premolars, human premolars are referred to as **3**s and **4**s (or **1**s or **2**s for the nonpaleontologically inclined), and molars can be **1**s, **2**s, or **3**s.

d. The **arcade** (or **arch**) from which a tooth originates specifies whether the tooth developed in the maxilla or in the mandible. The shorthand convention for indicating arch is to write the position numeral as superscript (*e.g.,* M^3) for maxillary (or upper) teeth, and to write the position numeral in subscript (*e.g.,* M_2) if the tooth is a mandibular (or lower) tooth. To avoid confusion in handwritten designations, draw a line above or below the numeral to indicate the intended position of the number.

e. Finally, the **side** from which the tooth originates — whether right or left — is designated by either **R** or **L**, respectively.

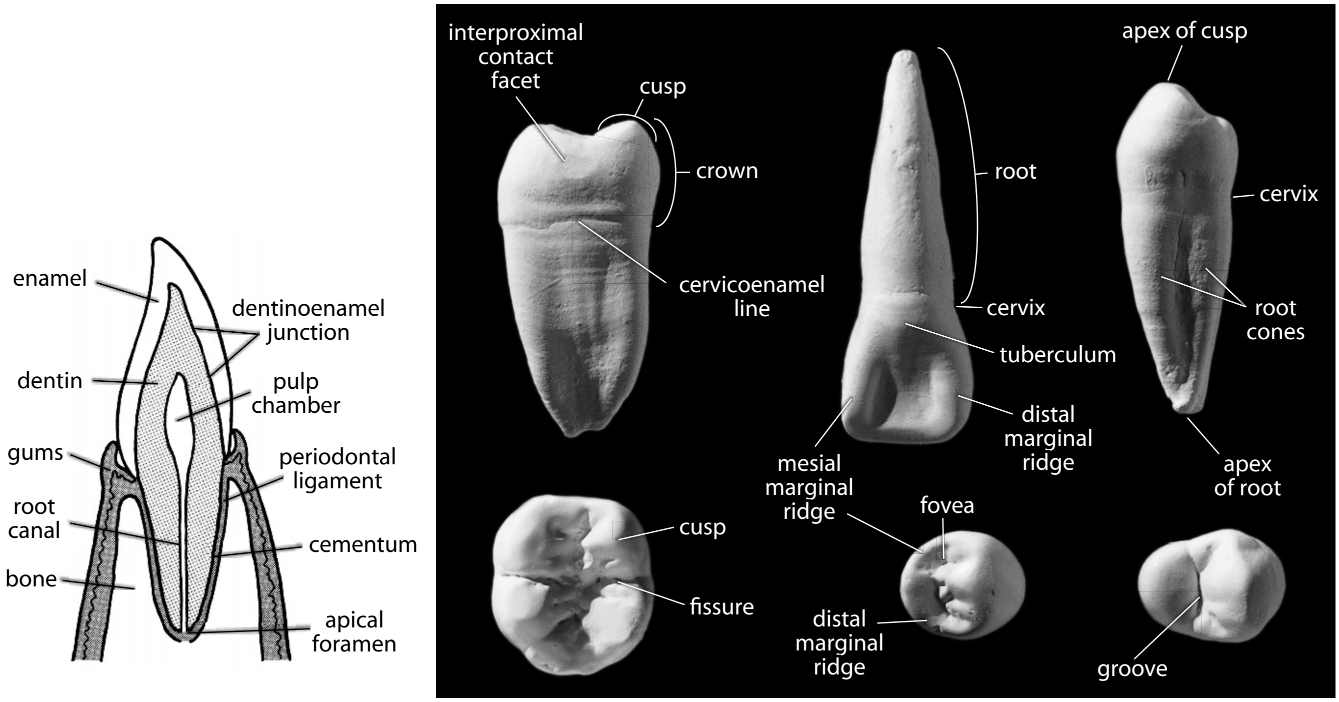


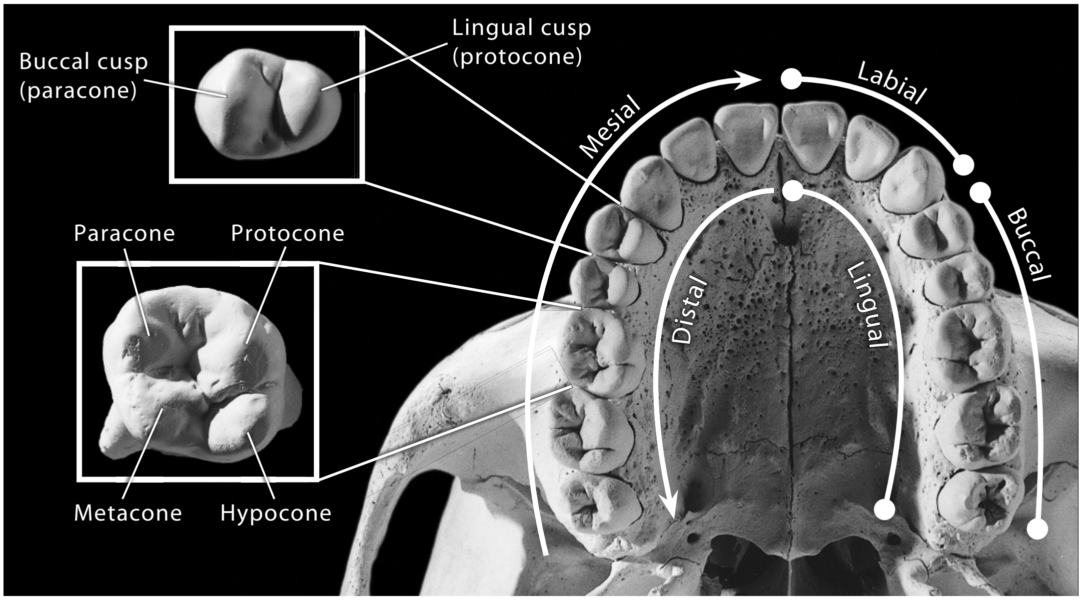
Figure 5.2 **Dental anatomy**. *Left:* sectioned tooth showing internal structure. *Right: top row, from left:* right lower second molar, mesial view; right upper central incisor, lingual view; right lower third premolar, mesial view. *Right: bottom row, from left:* left lower first molar, occlusal view; right lower fourth premolar, occlusal view; left upper third premolar, occlusal view. Shown twice natural size.

Using these conventions, the left deciduous second mandibular incisor is designated $\mathbf{Ldi_2}$, whereas the right permanent first maxillary molar is designated $\mathbf{RM^1}$. Because there is only one canine per arcade-side, some practitioners use an alternative system of nomenclature for the canines — a bar representing the occlusal plane is used to indicate position; thus $\overline{C}$ and $\underline{C}$ are more often used as synonyms than $\mathbf{C_1}$ and $\mathbf{C^1}$.

5.3 Anatomy of a Tooth

Figure 5.2 shows the various elements of a human tooth. There are some features so commonly found in teeth of all kinds that they are worth listing separately.

a. The **crown** is the part of the tooth covered by enamel.
b. The **root** is the part of the tooth that anchors the tooth in the alveolus of the mandible or maxilla. **Primary roots** are comprised of one or more **root cones** which may be completely fused (often discernible by shallow developmental grooves) or partially or completely bifurcated to become separate (secondary) roots.
c. **Enamel**, the specialized hard tissue that covers the crown, is both avascular and acellular. It is about 97% mineralized, essentially fossilized once it is formed.
d. **Cementum** is a bone-like tissue that covers the external surface of tooth roots.
e. **Dentin** (or **dentine**) is the tissue that forms the core of the tooth. This tissue has no vascular supply but is supported by the vascular system in the pulp and is lined on the inner surface (the walls of the pulp cavity) by odontoblasts, dentin-producing cells. These



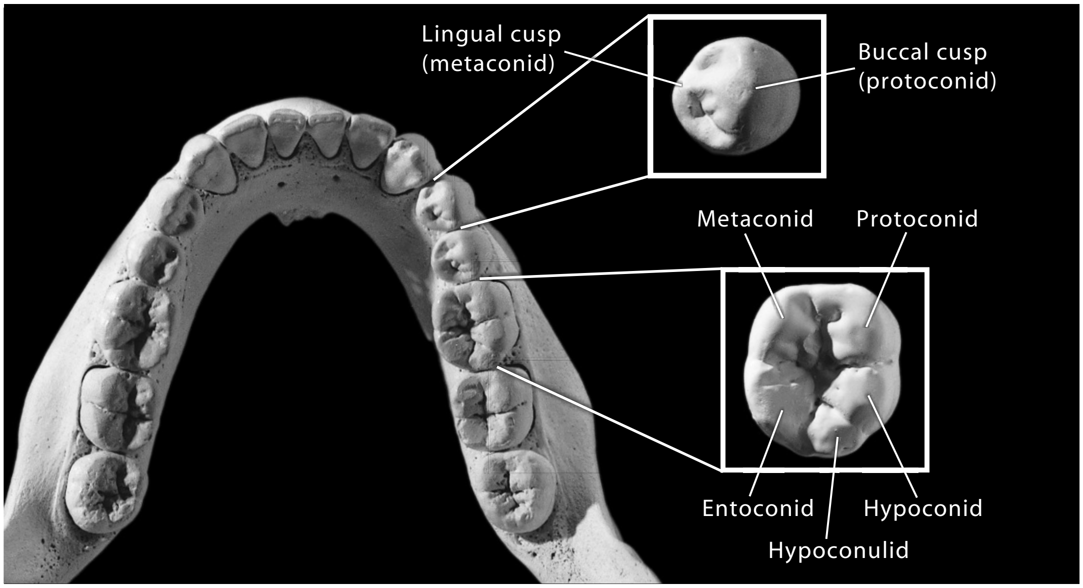


Figure 5.3 **Directional terms for teeth and major cusp names for teeth.** Arcades shown natural size; inset third premolars and first molars shown twice natural size.

cells have the same relationship to dentin that osteoblasts have to bone. Dentin underlies the enamel of the crown and encapsulates the pulp cavity, the central soft tissue space within a tooth. Occlusal wear may expose dentin, and because dentin is softer than enamel, the resulting exposures are usually occlusally concave.

f. The **cervix** (or **neck**) is the constricted part of the tooth at the junction of the crown and root.

g. The **cementoenamel** (or **cervicoenamel**) **line** (or **junction**) (**CEJ**) is the line encircling the crown at the cervix, marking the most rootward extent of the enamel.

h. The **dentinoenamel junction** (**DEJ** or **EDJ**) is the boundary between the enamel cap and the underlying dentin.

i. The **pulp chamber** is the expanded part of the pulp cavity at the crown end of the tooth.

j. The **root canal** is the narrow end of the pulp cavity at the root end of the tooth.

k. **Calculus** is a calcified deposit commonly found on the sides of tooth crowns. The origins of calculus lie with plaque, colonies of microorganisms that establish themselves on the teeth.

l. The **pulp** is the soft tissue within the pulp chamber. This includes nerves and blood vessels.

m. The **apical foramen** is the opening at each root tip, or **apex**, through which nerve fibers and vessels pass from the alveolar region to the pulp cavity.

n. A **cusp** is an occlusal projection of the crown. Major cusps on molars are named individually (Figure 5.3). Knowledge of relative cusp position, size, and wear is often valuable in identifying isolated teeth. Cusps of the upper teeth end with the suffix **-cone**, whereas cusps on the lower teeth end with the suffix **-conid**. The tip of a cusp is the **apex**.

The **protocone** is the mesiolingual cusp on an upper molar. Cusplets, grooves, or other topographic features on its mesiolingual surface are called **Carabelli's effects**.

The **hypocone** is the distolingual cusp on an upper molar.

The **paracone** is the mesiobuccal cusp on an upper molar.

The **metacone** is the distobuccal cusp on an upper molar.

The **protoconid** is the mesiobuccal cusp on a lower molar. Cusplets, grooves, or other forms on the mesiobuccal surface of the protoconid are called **protostylid effects**.

The **hypoconid** is the distobuccal cusp on a lower molar.

The **metaconid** is the mesiolingual cusp on a lower molar.

The **entoconid** is the distolingual cusp on a lower molar.

The **hypoconulid** is the fifth, distalmost cusp on a lower molar.

Cusplets on the incisal edges of unworn incisors are called **mamelons**.

o. A **crest** is a large elevated feature originating from a cusp. A **ridge** is a smaller, less-defined version of a crest.

p. A **cingulum** is a ridge of enamel that partly or completely encircles the sides of a tooth crown. While reduced or absent on human molars and premolars, it figures prominently in the crown morphology of incisors, canines, and deciduous molars.

q. A **tuberculum** is a bulge, derived from the cingulum, found on the lingual surface of incisors and canines near the cervical margin.

r. A **fissure** is a cleft on the occlusal surface between cusps. Fissures divide the cusps into patterns. The most widely acknowledged of these is the **Y-5 pattern**, a pattern in which the five lower molar cusps are arranged such that the metaconid and hypoconid contact each other across a short fissure.

s. A **groove** is a large, linear, trough-like fissure between cusps.

t. A **fovea** is a small, defined, often circular depression on a crown.

u. The primitive mammalian (**tribosphenic**) cusp pattern was a triad of cusps in both upper and lower molars. From this pattern, a remarkable variety of forms has arisen through evolution, ranging from the tall columnar molars of warthogs to the blade-like molars of some carnivores. In humans, as in most other primates, the mesial (anterior) part of the molar is referred to as the **trigon** (**trigonid** in lower molars). The distal (posterior) part of the primate molar, added onto the modified original triangle of cusps, is called the **talon** (or **talonid** in lower molars).

v. **Interproximal contact facets** (**IPCFs**) are facets formed between adjacent teeth in the same jaw; **occlusal contact facets** result from contact of mandibular and maxillary teeth during chewing.

In addition to these anatomical parts of teeth, a few additional terms used to describe and interpret teeth are also useful. **Supernumerary** teeth are extra teeth that exceed the expected number of teeth in any given tooth category. For example, supernumerary molars (fourth molars) are very rare in humans but more common in apes. **Agenesis** is the lack of tooth formation at a given position. **Hypoplasia** (hypomineralization) is a disturbance of enamel formation that often manifests itself in transverse lines, pits, or other irregularities on the enamel surface. **Hypercementosis** is a condition in which an excess of cementum forms on the root. **Taurodontism** refers to the condition in which the pulp chamber is expanded relative to the normal condition. **Caries** is a disease process resulting in the demineralization of dental tissues. **Shovel-shaped** incisors have strongly developed mesial and distal lingual marginal ridges, imparting a "shovel" appearance to the tooth. Several of these features are given further consideration in Chapters 19 and 21, where the uses of teeth in paleopathology and the study of populational affiliation are discussed.

5.4 Dental Development

Even before birth, germs of the deciduous teeth have formed within the jaws. When formation of each deciduous and permanent crown is complete and some root formation has occurred, it is erupted. When developing within the jaw, the **tooth buds**, or **germs**, reside in hollows in the alveolar bone called crypts. Within the crypt, calcification of the enamel cap of a tooth crown begins at the cuspal apices and proceeds **rootward**. Crown formation, including enamel calcification, is completed before eruption and before the roots are completely formed. The last parts of a tooth to develop, after eruption, are the root apices. Before replacements by their adult counterparts, the roots of the deciduous teeth are **resorbed** (eaten away by osteoclasts) prior to the shedding of each tooth. In Chapter 18 we describe the timing of these processes and discuss their use in aging subadult human dentitions.

Enamel is formed by cells called **ameloblasts** through a process known as **amelogenesis**. Unlike bone, dental tissues are usually not remodeled during life. Once formation of the enamel is complete, only changes through physical (wear) or chemical (decay) processes are possible. Dentin is formed by cells called **odontoblasts** through a process known as **dentinogenesis**. Primary dentin is laid down during tooth formation and secondary dentin is laid down during the stage of root maturation.

The processes of tooth genesis are similar in all mammals. The striking differences between mammalian tooth shape, size, and structure come as a result of the differing activity of the two cell types (ameloblasts and odontoblasts), and this activity is in turn regulated by the DNA. Thus, because of the stability of posteruptive form, teeth have a better possibility of more directly reflecting the genes than other parts of the skeleton. For these reasons, teeth are widely used in the assessment of biological distance between human populations (Chapter 21). Insults to the organism during the developmental span of any tooth, however, can directly affect the morphology of the tooth. An example of this is the phenomenon of **enamel hypoplasia** (discussed in Chapter 19).

Once erupted, teeth begin to wear away as they are used in mastication. Wear is usually most pronounced on the lingual occlusal surfaces of maxillary premolars and molars and on the buccal occlusal surfaces of mandibular premolars and molars. For anterior teeth, the wear pattern is more variable because these teeth are often used in **paramasticatory** functions (those besides simple biting and chewing; for instance, clamping a smoking pipe between the cheek teeth, or using the biting ability of the anterior dentition to serve as a kind of 'third hand' in processing animal hides). In general, occlusal wear is lingually biased on uppers, and labially biased on lower anterior teeth. Conditions of overbite, underbite, and edge-to-edge occlusion are some of the variants seen in humans.

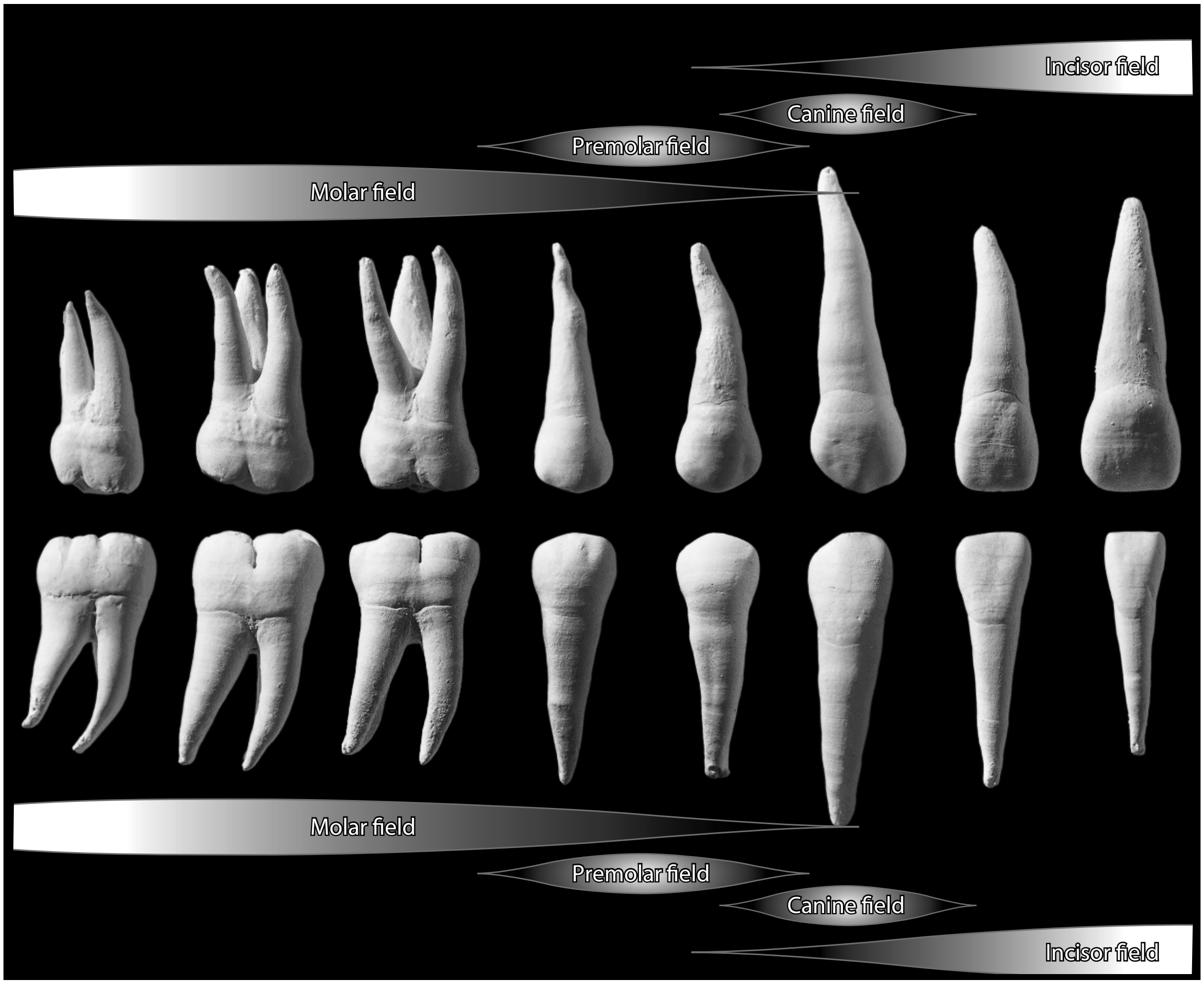


Figure 5.4 **A heuristic diagram illustrating the relative location and interplay of the dental morphogenic fields in humans**. With only minor modifications and name changes, this diagram could also represent the general effect of either the clone model or the homeobox code hypothesis of dental form. Teeth are shown at approximately 1.5 times normal size.

5.4.1 Dental Pattern Formation

How do the clumps of cells — first branchial arch ectoderm and neural crest ectomesenchyme — at the distal end of the dental arcade develop into molars, while the clumps of cells at the mesial end become incisors? Why do teeth at the boundary zone between two tooth categories tend to resemble each other more than those located further away from the boundary zone? These questions have been asked and debated for over 70 years, but the answers are still uncertain.

There are three primary hypotheses that account for dental patterning and differentiation: the **dental morphogenic field theory**, the **dental clone theory**, and the **odontogenic homeobox code hypothesis**.

In 1939, Butler proposed that the teeth forms in the fossil Cenozoic mammals he was studying were determined by their location relative to three dental morphogenic fields: incisor, canine, and molar. In 1945, Dahlberg applied Butler's dental morphogenic field concept to the human permanent dentition, and added a fourth dental field to account for premolar shape. Recently,

Hlusko and Mahaney (2009) tested Butler's hypothesis and found general support for the morphogenic field hypothesis, and also found evidence of some genetic distinction between molars and premolars. According to the morphogenic field model, each tooth primordium starts out as pluripotent (capable of differentiating into any of several ultimate forms), and the final form the tooth takes is influenced by its specific history of exposure to morphogens during growth. An M1 primordium exposed to the concentrated morphogens of a young molar field will end up looking more 'molar-like' than an M3 primordium exposed to the decreased concentration of morphogens of an aging field.

While the morphogenic field model holds that final tooth shape is the product of ectomesenchymal cells acquiring positional information from branchial arch ectoderm, the dental clone model holds that all the information necessary for the formation of tooth shape is contained in the ectomesenchymal cells themselves. According to the clone model, all teeth (both permanent and deciduous) of a given category of tooth originate as clones from a single progenitor (per arcade, per side). In this model, the first clones produced by a progenitor produce the most prototypical teeth, while later clones have increasingly reduced potency and, therefore, less fidelity to the prototypical ideal.

A last hypothesis, the odontogenic homeobox code hypothesis (Thomas and Sharpe, 1998; Sharpe, 2003; Cobourne and Sharpe, 2010), contends that signalling molecules within the oral epithelium exert time-dependent influence upon the ectomesenchymal cells by establishing specific homeodomains (domains of homeobox gene expression). Thus, for every tooth-producing region of the mandible and maxilla, there is a specific combination of homeobox genes within the oral epithelium that determine the ultimate morphology of the teeth that develop in those regions.

It is important to note that the odontogenic homeobox code hypothesis is based on studies of gene expression and gene knock-out studies of mice, while the former two hypotheses are based on phenotypic data and have no basis in genetics whatsoever. In any case, these hypotheses are not necessarily competing or mutually exclusive. For the purposes of this chapter, the most important lessons to be garnered are these:

- The ultimate morphology of a tooth results from a complex interaction of location, timing, and genetic regulation.
- Teeth of the same category are influenced by many of the same genes, and there is some genetic distinction between different categories of teeth.
- Teeth at the boundaries between tooth categories tend to look more like the adjacent tooth category than teeth located further from the boundary.

5.5 Tooth Identification

Because teeth are often found separated from the jaws that originally held them, because they are relatively abundant, and because of their importance in osteological work in forensics, archaeology, and paleontology, it is important to be able to identify isolated teeth fully and accurately. A full and exact identification of each of the 20 deciduous and 32 permanent human teeth seems like a formidable task, but with a little organization and an appropriate analytical framework, the job can be considerably simplified.

Mammalian teeth reflect millions of years of evolution. As a general rule, the variation between different tooth categories has been reduced in humans (becoming "homogenized"), whereas morphological variation at each tooth position has tended to increase. Thus, compared to the teeth of even our closest relatives the apes, human teeth are more difficult to identify. For those interested in the range of variation commonly encountered in human teeth, we recommend Taylor (1978) and Scheid (2007).

In both apes and humans, it is easy to distinguish between the anterior teeth (incisors and canines) and the posterior teeth (molars). With only slightly more difficulty, you can determine whether teeth are incisors, canines, premolars, or molars. Most problems of identification come in distinguishing left from right, maxillary teeth from mandibular teeth, deciduous teeth from permanent teeth, and recognizing the different tooth positions. A few hints and an organizational structure greatly facilitate the study and recognition of individual teeth.

The steps toward identification of isolated teeth are outlined here in a logical order. It should prove possible to identify virtually all unworn and most worn human teeth by following this order. When using the identification criteria presented in this chapter, always keep variation in mind. Note the degree of wear on any tooth you examine; many of the identification criteria rely on the tooth being human, with minimal wear. When identifying a worn tooth, attempt to mentally reconstruct the original, unworn crown morphology and overall proportions. Only through experience with a range of human teeth will the researcher become familiar with the normal, expected variation within the human species. Thus, when it is not initially obvious whether the tooth is human, working through the steps in detail may make it possible to identify and eliminate nonhuman teeth. Worn bear and pig teeth may resemble human teeth superficially, but moderate experience with modest samples of worn and unworn human teeth will almost always be adequate to allow an accurate diagnosis.

While many shortcuts to identification are available, remember that there is no single, magic criterion that will always successfully distinguish one tooth from all others. Shortcuts will give you a good idea of the direction you should follow in your analysis, but you should always use multiple criteria for each identification, checking each one independently and making your decision based on the preponderance of the evidence whenever there is conflict. The criteria to check include the overall crown **profile** (shape) from different views; the number, location, and size of cusps, fissures, foveae, and other crown morphology; the number, location, and orientation of roots; the presence, placement, and shape of interproximal contact facets; and the location and orientation of occlusal contact facets.

Many of the criteria presented here for identifying modern human teeth are relative, and hence dependent on comparing one observation, index, or size against another. Thus, some of the comparative criteria may be difficult to evaluate at first, but they will quickly become easier as you examine more and more teeth. Remember that every student of osteology conveniently carries around a full or partial comparative adult dentition within the mouth at all times. For identifications of category, arcade, position, and side, the osteologist may find it useful to imagine properly placing the unidentified tooth into his or her own dentition. Whether identifying isolated teeth or just fragments of teeth, it is often helpful to proceed in the order of the questions presented below. An alternative "Key" approach to tooth identification is presented in Appendix 2.

Except where otherwise stated, all images of teeth in this chapter are reproduced at twice natural size. Root orientation in mesial, buccal, labial, and lingual views is anatomical (maxillary roots point up, toward the top of the page). Occlusal views are shown with the mesial crown edge toward the top of the page. Note that the enamel of the illustrated teeth does not appear shiny. Enamel is normally translucent and shiny, but these characteristics combine to obscure crown topography in photographs. To solve this problem, we coated the teeth illustrated here with an opaque, thin pigment prior to photography (Appendix 1).

5.6 To Which Category Does the Tooth Belong? (Figure 5.5)

5.6.1 Incisors

- Incisor crowns are flat and blade-like.
- The outline of the occlusal dentine patch of the incisor exposed by wear is rectangular or square.

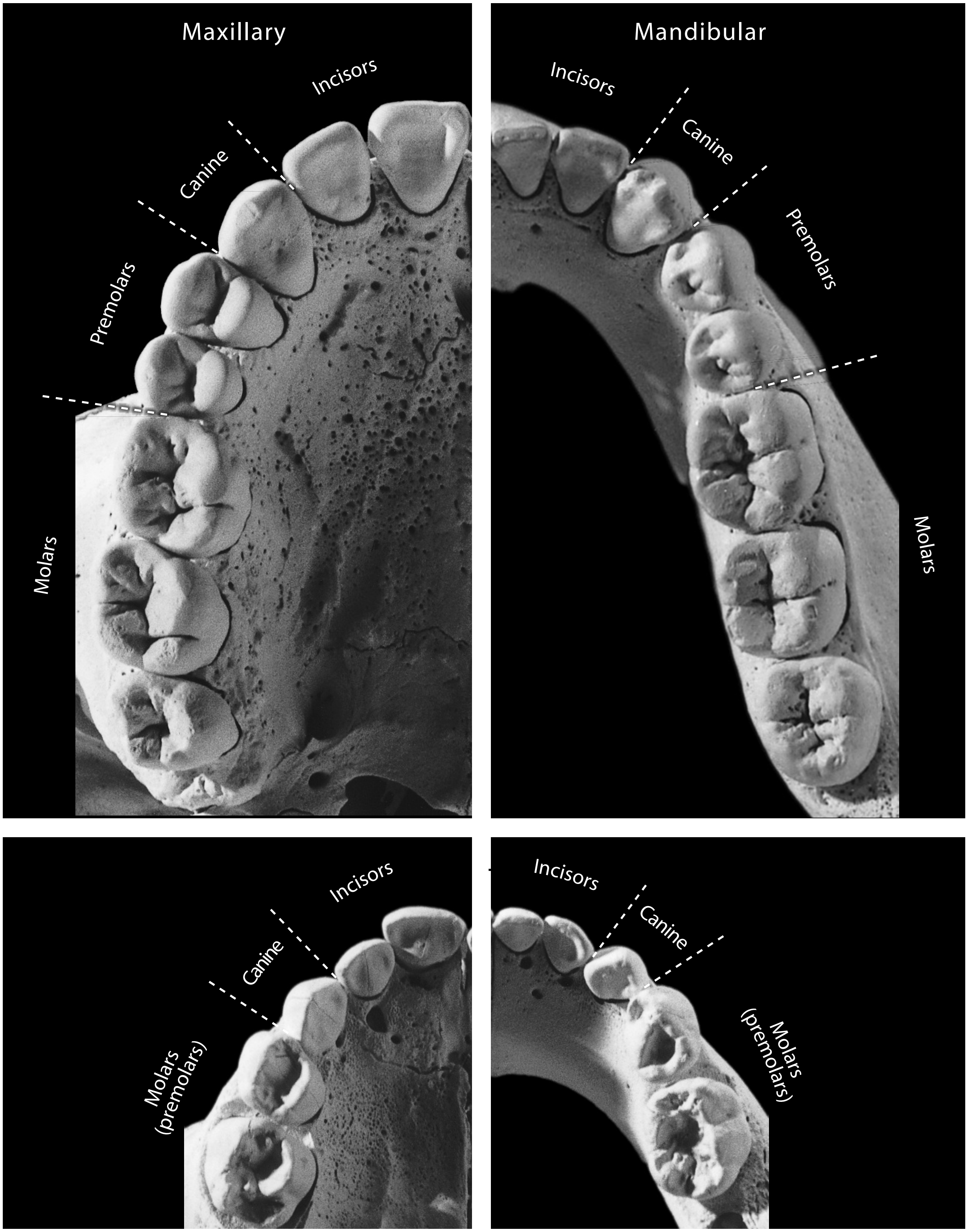


Figure 5.5 **A comparison of maxillary and mandibular right half arcades for permanent** (*top*) **and deciduous** (*bottom*) **dentitions**. Occlusal, right side, twice natural size.

5.6.2 Canines

- Canine crowns are conical and tusklike.
- The outline of the occlusal dentine patch of the canine exposed by wear is diamond shaped.
- Canine roots are longer than other roots in the same dentition.
- Some canines may be confused for incisors. Note, however, the longer, larger canine root relative to crown height and the oval canine crown cross section.

5.6.3 Premolars

- Premolar crowns are round, shorter than canine crowns, and smaller than molar crowns. They usually have two cusps.
- Premolars are usually single rooted.
- Some lower third premolars may be mistaken for canines. Note, however, the smaller crown height and shorter root of the premolar.

5.6.4 Molars

- Molar crowns are larger, squarer, and bear more cusps than other teeth.
- Molars usually have multiple roots.
- Reduced third molars are sometimes mistaken for premolars. To avoid this, note the relationship of root length to crown height, the round or oval outline of the premolars in occlusal aspect, and the comparatively regular cusp pattern on the premolar crowns.

5.7 Is the Tooth Permanent or Deciduous? (Figure 5.6)

5.7.1 Diagnostic Criteria

- To identify deciduous teeth, adult criteria outlined both above and below are applicable (except where indicated in Special Cases, section 5.7.2, below).
- Deciduous crowns have enamel that is thinner relative to crown size.
- Deciduous tooth crowns are more bulbous in shape, with the enamel along the crown walls often bulging out above the enamel line more prominently than in permanent teeth.
- Deciduous tooth roots are thinner and shorter. The deciduous molar roots are more divergent.
- Deciduous tooth roots are often partly resorbed, particularly below the crown center of deciduous molars.

5.7.2 Special Cases

- Deciduous first upper and lower molar crowns have peculiar shapes. The upper is triangular in outline, with a strongly projecting buccal paracone surface. The lower has a low talonid and an extensive buccal protoconid surface.
- Deciduous upper canines differ from adult upper canines in that the mesial occlusal edge is generally longer than the distal occlusal edge.

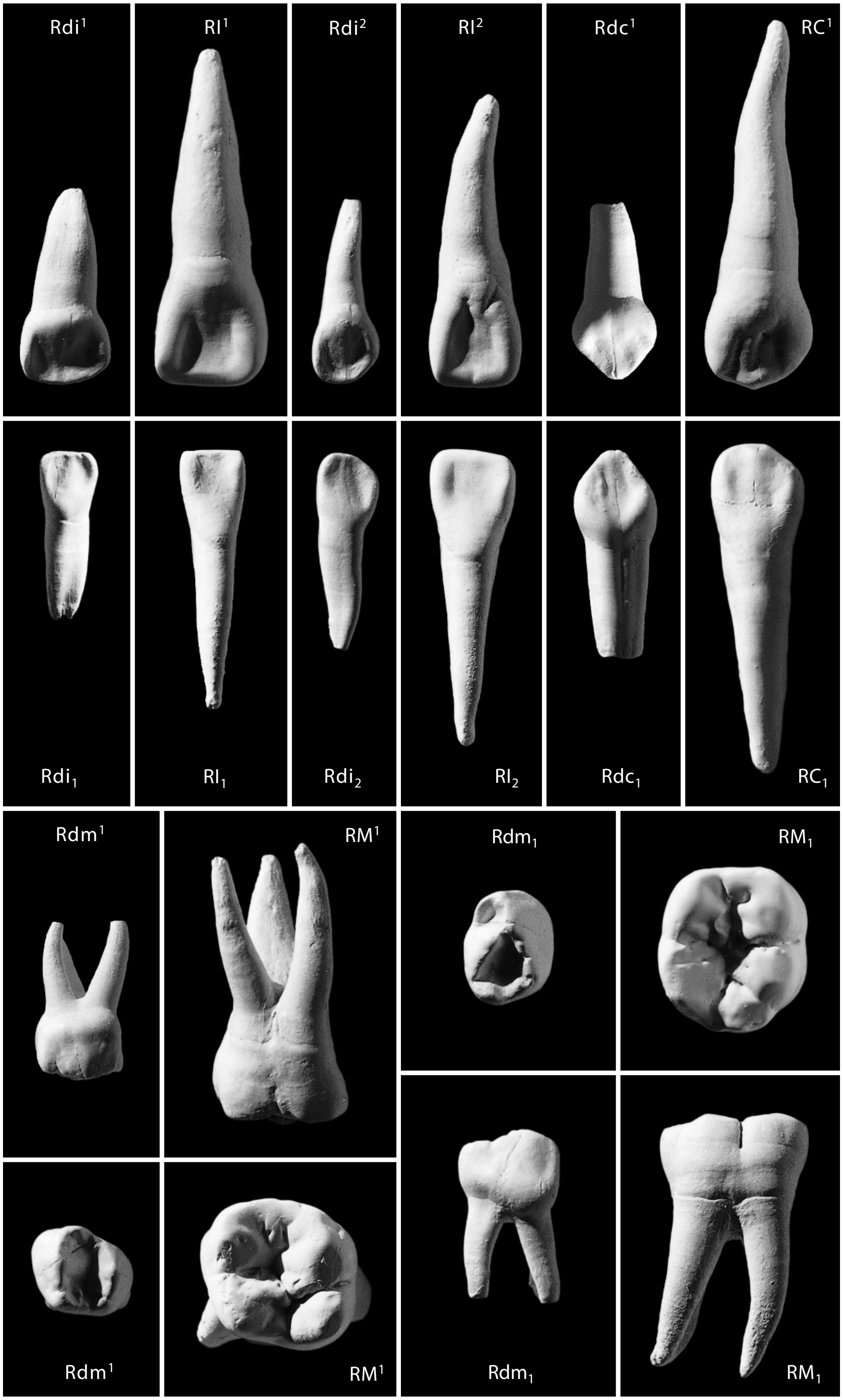


Figure 5.6 **Deciduous and permanent teeth compared.** Incisors and canines in lingual view; molars in buccal and occlusal views. Right side, twice natural size.

5.8 Is the Tooth an Upper or a Lower?

To identify deciduous teeth, adult criteria outlined both above and below are applicable.

For incisors and canines, view the crown lingually. Gauge the maximum mesiodistal length and maximum crown height (correcting the latter for wear if necessary). When the height dimension is twice the length (*i.e.,* tall narrow crowns), the tooth is probably a lower.

For molars, determine the mesiodistal crown axis by observing the placement of the protocone or protoconid (mesial and lingual, and mesial and buccal, respectively; the largest and most heavily worn cusp) and the disposition of the interproximal contact facets (IPCFs), which must be mesial and distal.

5.8.1 Upper versus Lower Incisors (Figure 5.7)

- Upper incisor crowns are broad (mesiodistally elongate) relative to their height. Lower incisor crowns are narrow compared to their height.
- Upper incisor crowns have much lingual relief. Lower incisor crowns have comparatively little lingual topography.
- Upper incisor roots are usually more circular in cross section. Lower incisor roots are usually more mesiodistally compressed in cross section.

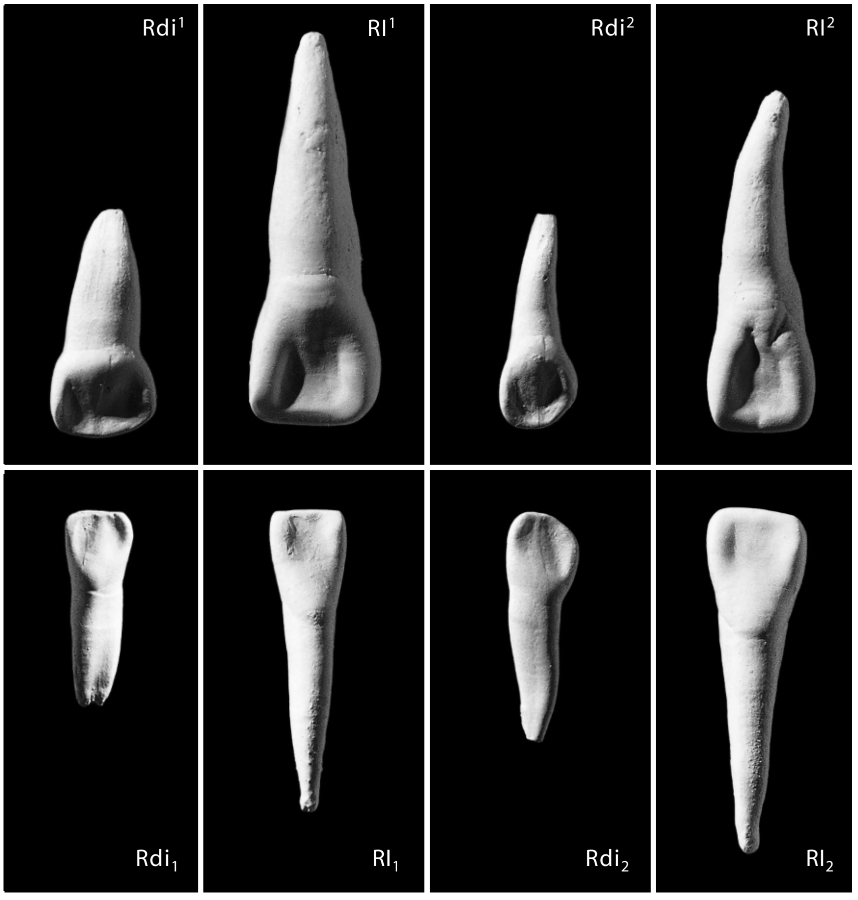
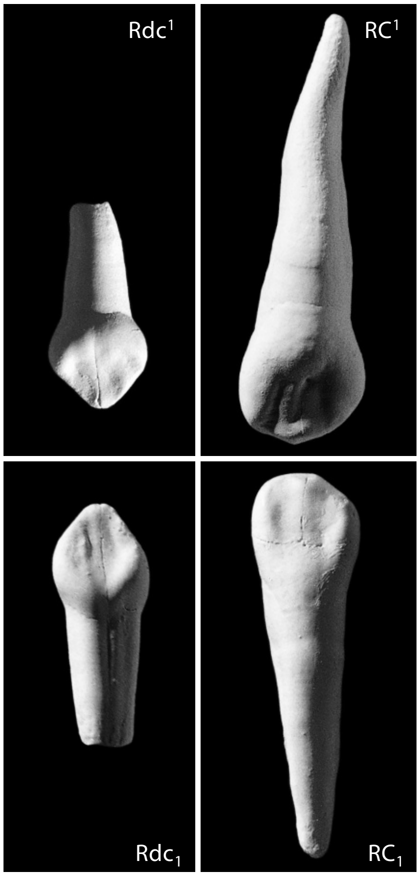


Figure 5.7 **Upper and lower deciduous and permanent incisors compared.** Right side, lingual view, twice natural size.



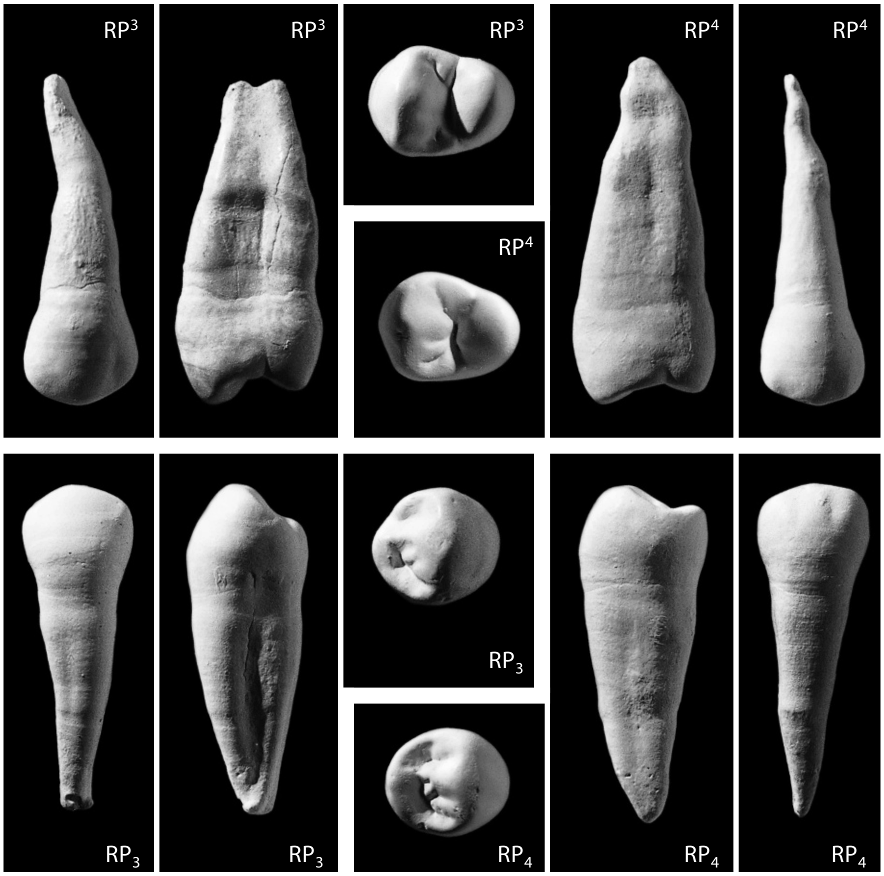


Figure 5.8 **Upper and lower deciduous and permanent canines compared**. Right side, lingual view, twice natural size.

Figure 5.9 **Upper and lower permanent premolars compared**. Right side, buccal, mesial, and occlusal views, twice natural size.

5.8.2 Upper versus Lower Canines (Figure 5.8)

- Upper canine crowns are broad (mesiodistally elongate) relative to their height. Lower canine crowns are narrow relative to their height.
- Upper canine crowns have much lingual relief. Lower canines have comparatively little lingual relief.
- Upper canine crowns have apical wear that is mostly lingual. Lower canines have apical occlusal wear that is mostly labial.

5.8.3 Upper versus Lower Premolars (Figure 5.9)

- Upper premolar crowns have two cusps of nearly equal size. Lower premolar crowns show comparatively high disparity in buccal and lingual cusp size, with the buccal cusp dominating the lingual in height and area.
- Upper premolar crowns have strong occlusal grooves oriented mesiodistally (median grooves) between the major cusps. Lower premolar crowns have comparatively weak median grooves.
- Upper premolar crowns are more oval in occlusal outline. Lower premolar crowns are more circular in occlusal outline.

5.8.4 Upper versus Lower Molars (Figure 5.10)

- Upper molar crowns usually have three or four major cusps. Lower molar crowns usually have four or five major cusps.
- Upper molar crowns have outlines in the shape of a rhombus (skewed rectangle) in occlusal view. Lower molar crowns have square, rectangular, or oblong outlines.
- Upper molar crowns have cusps placed asymmetrically relative to the mesiodistal crown axis. Lower molar crowns have cusps placed symmetrically about the crown midline.
- Upper molars usually have three major roots that are variably fused. Lower molars usually have two major roots but occasionally have three.

5.9 What is the Position of the Tooth?

5.9.1 Upper Incisors: I^1 versus I^2 (Figure 5.11)

- Upper central incisor (I^1) crowns are larger than upper lateral incisor (I^2) crowns.
- Upper central incisor (I^1) crowns have a greater mesiodistal length:height ratio than upper lateral incisor (I^2) crowns in labial view.
- Upper central incisor (I^1) crowns are more symmetrical in labial view than upper lateral incisor (I^2) crowns.
- Upper central incisor (I^1) roots are shorter and stouter relative to crown size than upper lateral incisor (I^2) roots.

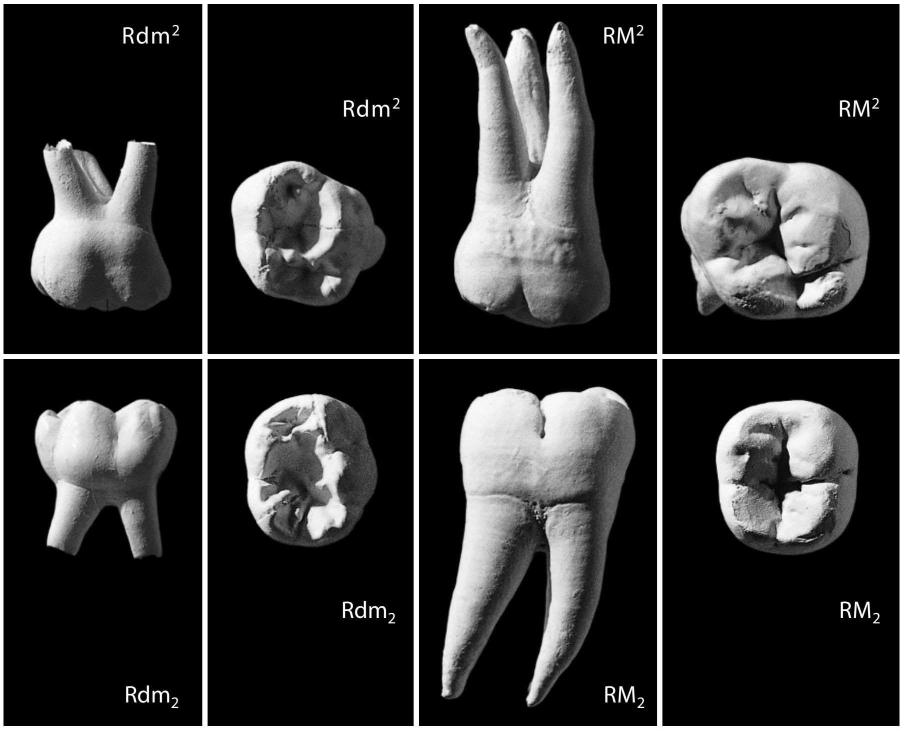


Figure 5.10 **Upper and lower deciduous and permanent molars compared**. Right side, buccal and occlusal views, twice natural size.

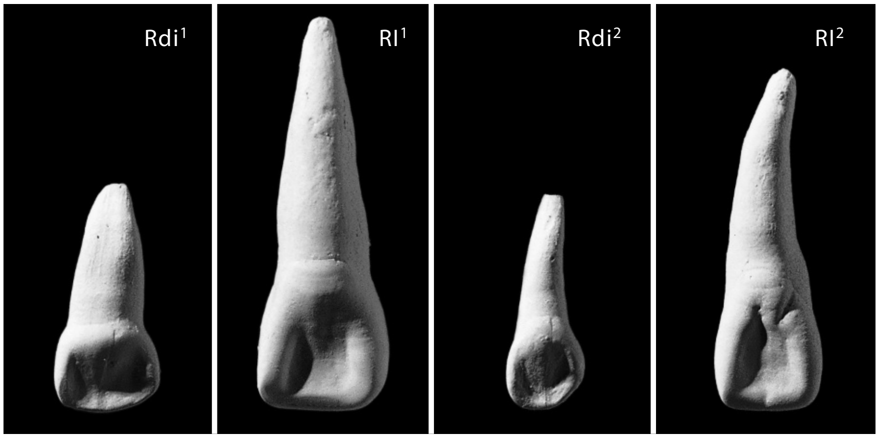


Figure 5.11 **Upper deciduous and permanent incisors compared**. Right side, lingual view, twice natural size.

5.9.2 Lower Incisors: I_1 versus I_2 (Figure 5.12)

- Lower central incisor (I_1) crowns are slightly smaller than lower lateral incisor (I_2) crowns.
- Lower central incisor (I_1) crowns have a smaller mesiodistal length: height ratio than lower lateral incisor (I_2) crowns in labial view.
- Lower central incisor (I_1) crowns are slightly more symmetrical in labial view than lower lateral incisor (I_2) crowns; the distal I_2 crown edges flare distally in this view.
- Lower central incisor (I_1) roots are shorter, both relative to crown height and absolutely, than I_2 roots.

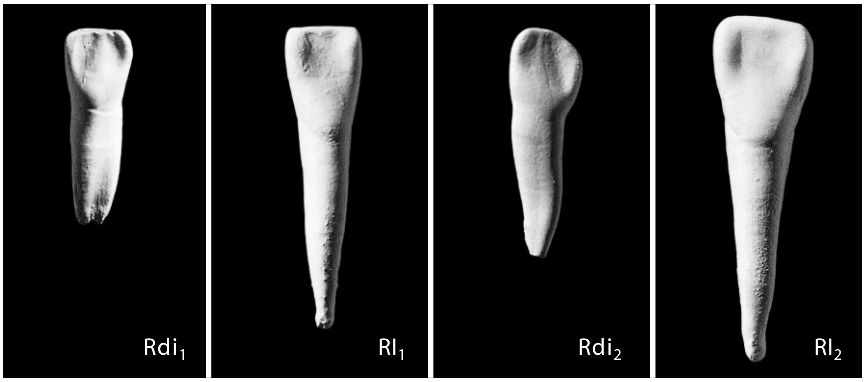


Figure 5.12 **Lower deciduous and permanent incisors compared**. Right side, lingual view, twice natural size.

5.9.3 Upper Premolars: P^3 versus P^4 (Figure 5.13)

- Upper third premolar (P^3) crowns have major lingual cusps that are small compared to major buccal cusps. Upper fourth premolar (P^4) crowns have major buccal and lingual cusps of more equivalent size in occlusal view.
- Upper third premolar (P^3) crowns have less symmetric, more triangular outlines in occlusal view than upper fourth premolar (P^4) crowns. The latter are rounder because the relative mesiodistal length of the major buccal cusp is not as great as in the P^3 crown (the lingual cusp of the P^4 crown is relatively larger in both length and area).

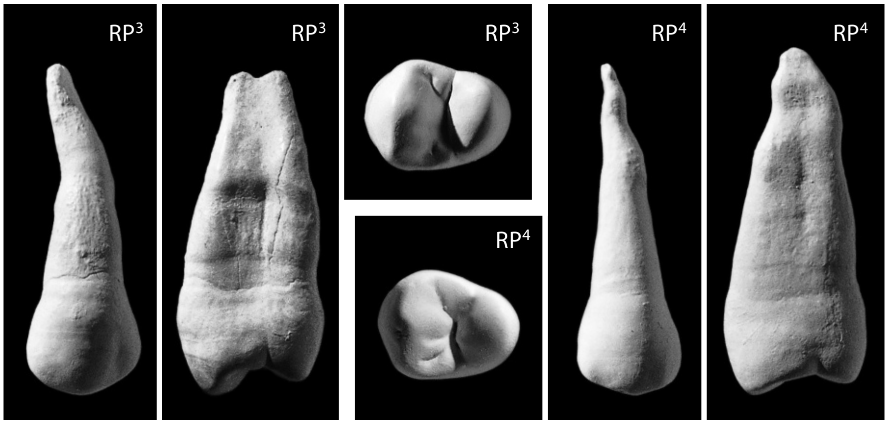


Figure 5.13 **Upper permanent premolars compared.** Right side, buccal, mesial, and occlusal views, twice natural size.

- Upper third premolar (P^3) crowns have more concave mesial surfaces and more deeply indented mesial occlusal outlines than upper fourth premolar (P^4) crowns.
- Upper third premolar (P^3) crowns show more mesiobuccal projection of the cervicoenamel line than upper fourth premolar (P^4) crowns.
- Upper third premolar (P^3) crowns contact mesially with the canine. The resulting small mesial IPCF is distinctive, usually curved, and vertically elongate. The mesial IPCF on the upper fourth premolar (P^4) is usually more symmetrical and buccolingually elongate.
- Upper third premolar (P^3) roots are usually double, bilobate, or apically bifurcated. Upper fourth premolar (P^4) roots are usually single.

5.9.4 Lower Premolars: P_3 versus P_4 (Figure 5.14)

- Lower third premolar (P_3) crowns have a major lingual cusp that is small, relative to the dominant major buccal cusp, in both occlusal area and height. The major lingual cusp is often expressed merely as a small lingual ridge. Lower fourth premolar (P_4) crowns have major buccal and lingual cusps of more equivalent size, and the major buccal cusp is less pointed than on a P_3 crown.

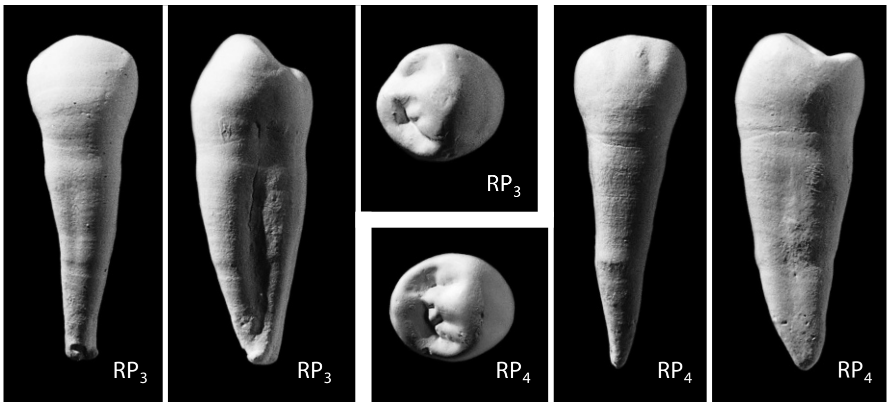


Figure 5.14 **Lower permanent premolars compared.** Right side, buccal, mesial, and occlusal views, twice natural size.

- Lower third premolar (P_3) crowns have a mesial fovea placed very mesially, close to the mesial occlusal edge in occlusal view. Lower fourth premolar (P_4) crowns have more distally placed mesial foveae.
- Lower third premolar (P_3) crowns have less symmetry of occlusal outline than lower fourth premolar (P_4) crowns.
- Lower third premolar (P_3) crowns have much smaller talonids than lower fourth premolar (P_4) crowns.
- Lower third premolar (P_3) crowns bear mesial (canine) IPCFs analogous to those discussed earlier for the upper counterparts.

5.9.5 Upper Molars: M^1 versus M^2 versus M^3 (Figure 5.15)

- Upper first molar (M^1) crowns have four well-developed cusps arranged in a rhombic shape. Upper third molars (M^3) tend to be smaller and more crenulate (furrowed on the occlusal surface) than first molars, with more irregular cusp positioning relative to the major crown axes. Upper third molars (M^3) usually lack a hypocone in humans. Upper second molar (M^2) crowns are intermediate to the first and third molar crowns in morphological attributes.

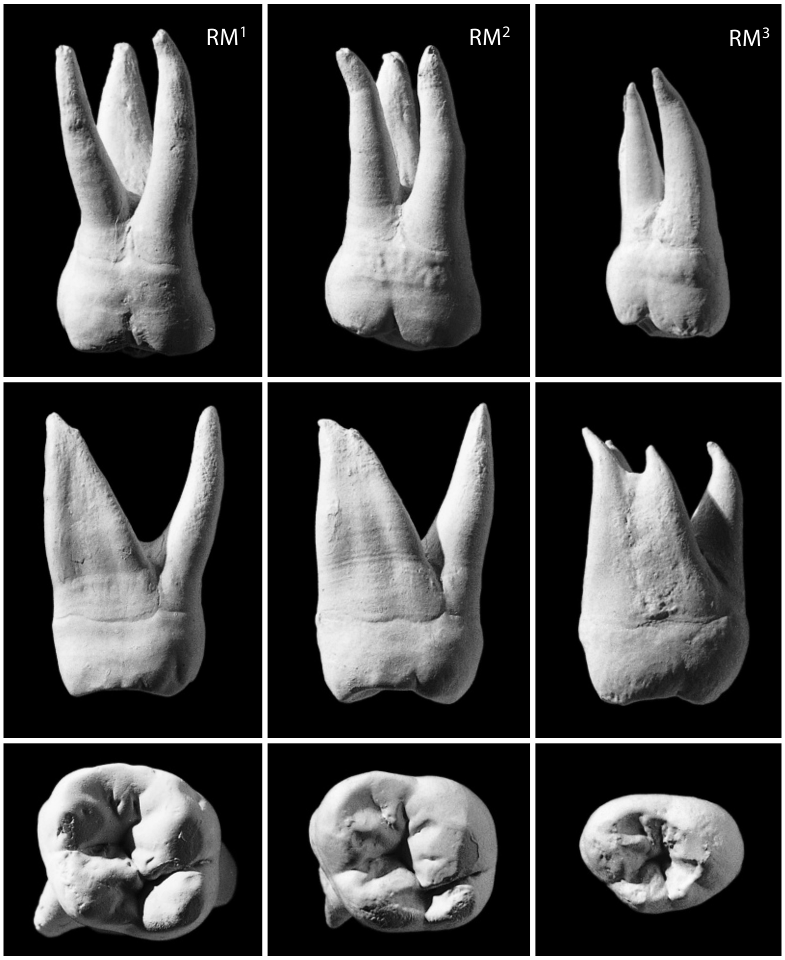


Figure 5.15 **Upper permanent molars compared.** Right side, buccal, mesial, and occlusal views, twice natural size.

- Upper first molars (M^1) have three long, separate, and divergent roots. Upper third molars (M^3) tend to have fused roots and lack distal IPCFs. Upper second molar (M^2) roots are intermediate.

5.9.6 Lower Molars: M_1 versus M_2 versus M_3 (Figure 5.16)

- Lower first molar (M_1) crowns have five well-developed cusps usually arranged in the classic Y-5 pattern. Lower third molars (M_3) usually have four or fewer cusps with more variable arrangement. Lower third molars (M_3) tend to be smaller and more crenulate than first molars, with more irregular cusp positioning relative to the major crown axes. Lower second molar (M_2) crowns are intermediate to the first and third molar crowns in morphological attributes.
- Lower first molars (M_1) have two long, separate, and divergent roots. Lower third molars (M_3) tend to have fused roots and lack distal IPCFs. When the mesial and distal roots remain separate, the distal one is post-like, set below a rounded posterior crown profile. Lower second molar (M_2) roots are intermediate.

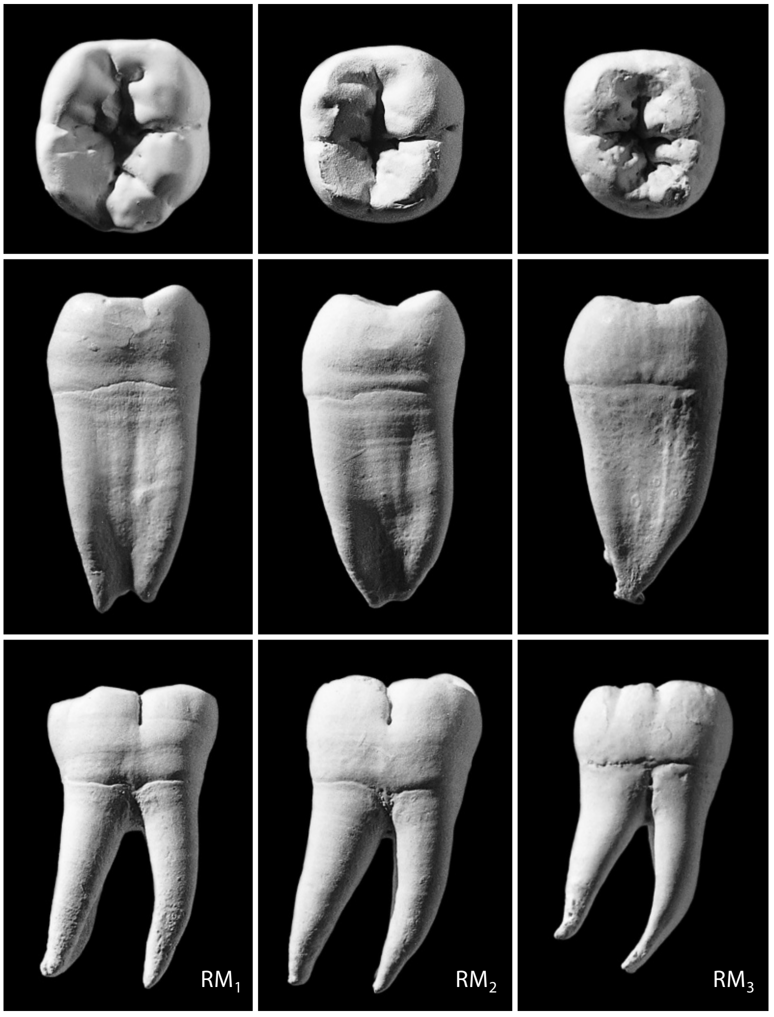


Figure 5.16 **Lower permanent molars compared.** Right side, occlusal, mesial, and buccal views, twice natural size.

5.10 Is the Tooth from the Right or the Left Side?

5.10.1 Upper Incisors (Figure 5.17)

Make the first two observations in labial view, orienting the specimen as it would rest in dentition, with the occlusal surface horizontal. The root axis angles posterolaterally in the maxilla. The distal occlusal corner is more rounded than the mesial.

- The long axis of the root angles distally relative to the vertical (cervicoincisal) axis of the crown, with the root tip usually leaning distally.
- The I^1/I^1 IPCF is more planar (flatter), wider, and more symmetrically placed than the more irregular, vertically elongate I^1/I^2 IPCF.
- The distal root surface is more deeply grooved than the mesial root surface.

5.10.2 Lower Incisors (Figure 5.17)

Make the first, third, and fourth observations in labial view, orienting the specimen as it would rest in dentition, with the occlusal surface horizontal.

- The root axis angles posterolaterally.
- The distal occlusal corner is more rounded than the mesial.

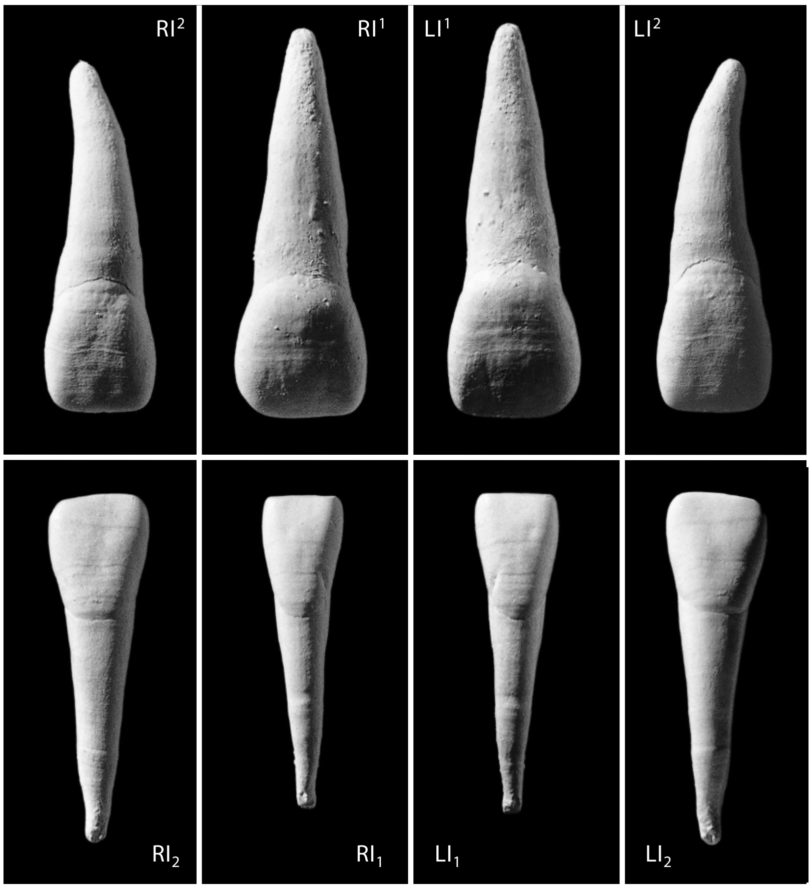


Figure 5.17 **Right and left upper and lower permanent incisors**. Labial view, twice natural size.

- The I_1/I_1 IPCF is more planar (flatter) and symmetrically placed than the I_1/I_2 IPCF.
- The occlusal wear most often angles distally and inferiorly relative to the vertical (cervicoincisal) axis of the crown.
- The long axis of the root angles distally relative to the vertical (cervicoincisal) axis of the crown, with the root tip usually leaning distally.

5.10.3 Upper Canines (Figure 5.18)

Make the first two observations in labial view with the tooth oriented as it would rest in dentition.

- The mesial occlusal edge (ridge joining crown shoulder with apex) is usually shorter than the distal occlusal edge.
- The long axis of the root angles distally relative to the vertical (cervicoincisal) axis of the crown.
- The distal IPCF (for P^3) is usually larger and especially broader than the mesial (lateral incisor) IPCF.

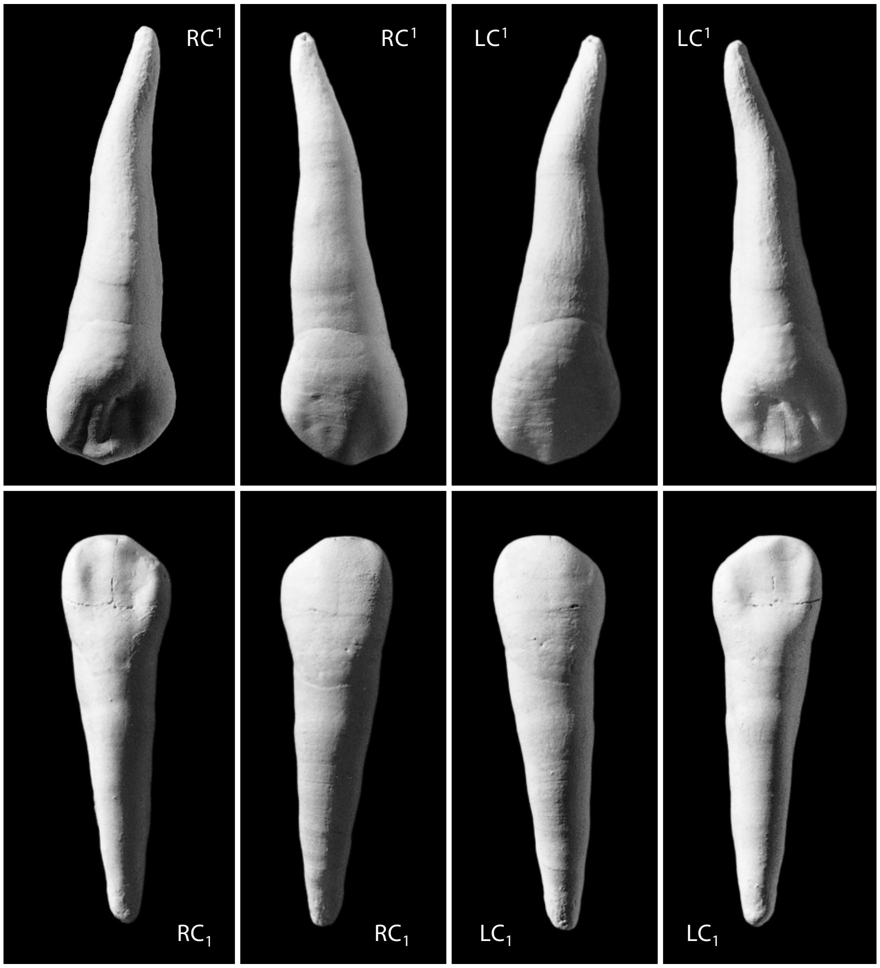


Figure 5.18 **Right and left upper and lower permanent canines.** Lingual and labial views, twice natural size.

- The distal root surface is more deeply grooved than the mesial root surface.
- The mesial enamel line has a higher crownward arch.

5.10.4 Lower Canines (Figure 5.18)

All of the criteria used to side upper canines are applicable to lower canines.

5.10.5 Upper Premolars (Figure 5.19)

- IPCFs (when present) are mesial and distal, and the major median groove between cusps is oriented mesiodistally.
- The major lingual cusp is centered mesially relative to the major buccal cusp. Note for worn teeth that the center of the dentine exposure usually corresponds to the placement of the original cusp apex.
- The major lingual cusp is smaller, less occlusally prominent, and usually more heavily worn than the major buccal cusp.
- The long axis (axes) of the root(s) angle(s) distally relative to the vertical (cervicoincisal) axis of the crown.

5.10.6 Lower Premolars (Figure 5.19)

- The IPCFs (when present) are mesial and distal.
- The major buccal cusp is larger, more occlusally prominent, and usually heavily worn more than the major lingual cusp.
- The major lingual cusp is centered mesially relative to the main buccolingual axis of the crown in occlusal view.
- The talonid, if present, is distal.
- The long axis (axes) of the root(s) angle(s) distally relative to the vertical (cervicoincisal) axis of the crown.

5.10.7 Upper Molars (Figure 5.20)

- IPCFs (when present) are located on the mesial and distal crown faces.
- The protocone is the largest, most heavily worn cusp. It occupies the mesiolingual crown corner.
- The hypocone is the smallest (sometimes absent) cusp. It occupies the distolingual crown corner.
- Lingual cusps are less prominent than buccal cusps and have heavier wear.
- In occlusal view, the lingual crown surface is more visible than the buccal crown surface.
- The largest of the three roots is often compressed buccolingually and set beneath the protocone and hypocone.
- The two smaller roots are rounder and set buccally (one mesial and one distal), and the mesiobuccal root is usually larger.
- All roots angle distally with respect to the major crown axes.

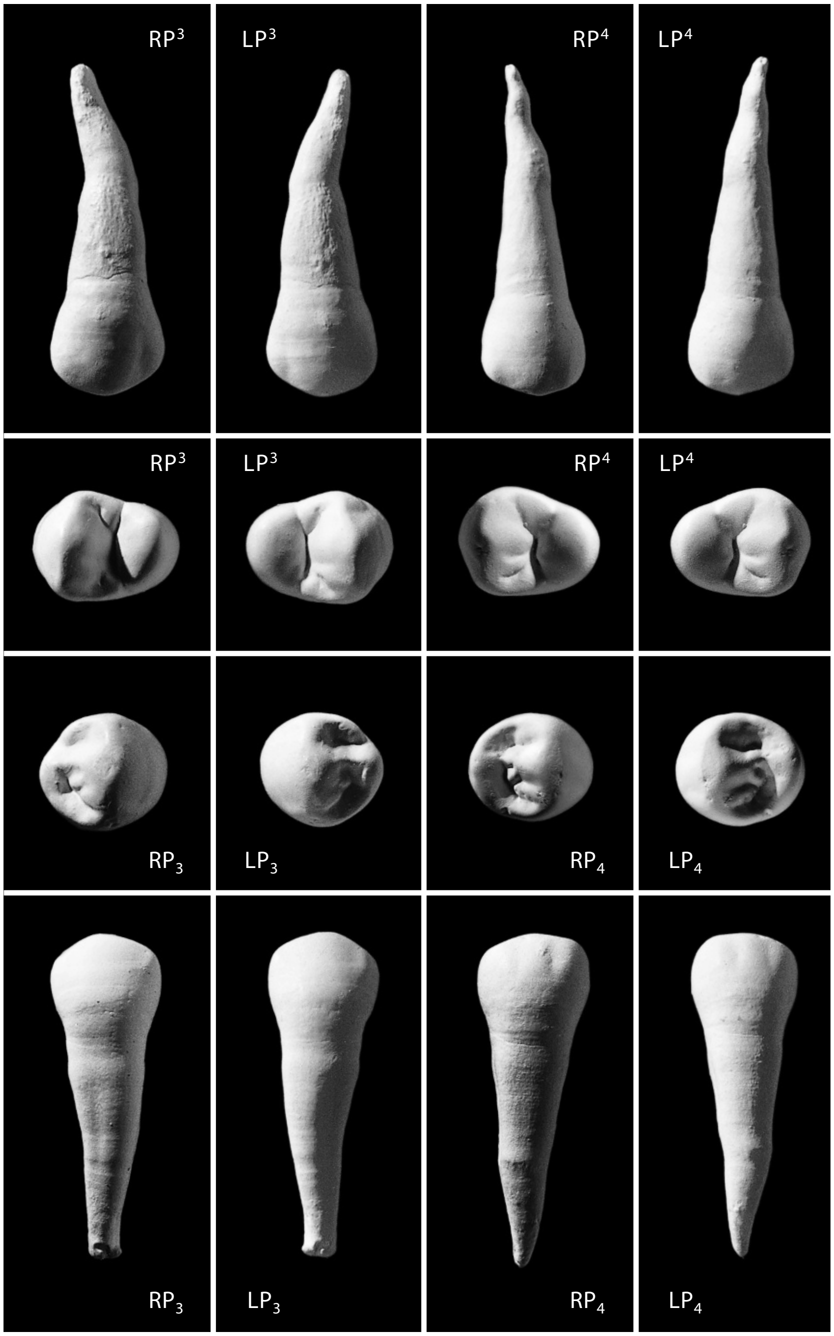


Figure 5.19 **Right and left upper and lower permanent premolars**. Buccal and occlusal views, twice natural size.

5.10.8 Lower Molars (Figure 5.20)

- IPCFs (when present) are located on the mesial and distal crown faces.
- The longest crown axis is usually mesiodistal.
- The protoconid is the largest, most heavily worn cusp. It occupies the mesiobuccal crown corner.
- The hypoconulid is the smallest cusp (unless there are additional, smaller cusps, labeled C-6, C-7, and so on). It is placed distally and centered on the mesiodistal crown axis.

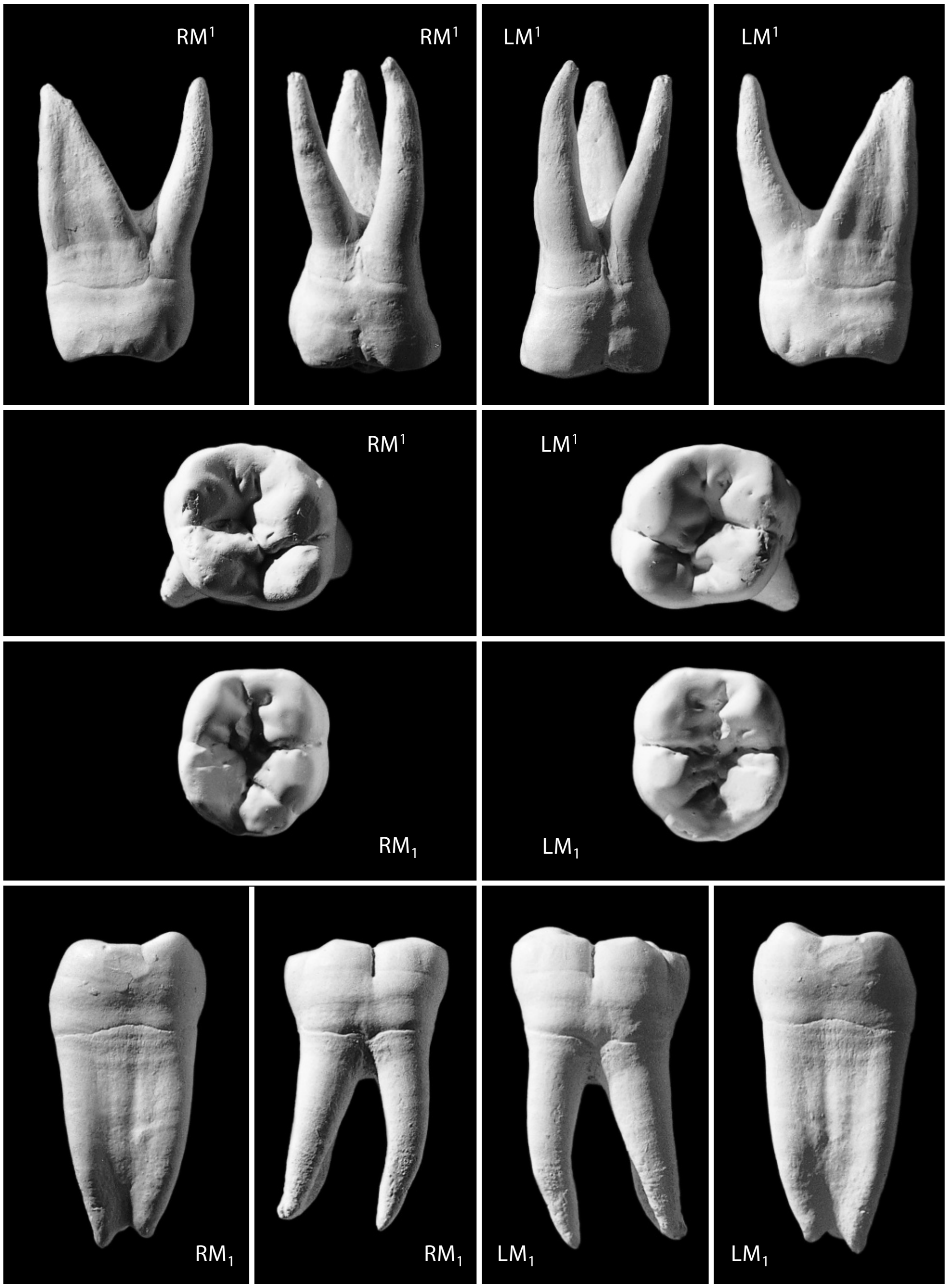


Figure 5.20 **Right and left upper and lower permanent molars.** Mesial, buccal, and occlusal views, twice natural size.

- The buccal cusps are occlusally less prominent than the lingual cusps and have heavier wear.
- The two major roots are compressed mesiodistally and set under the mesial and distal crown halves.
- All roots angle distally with respect to the major crown axes.

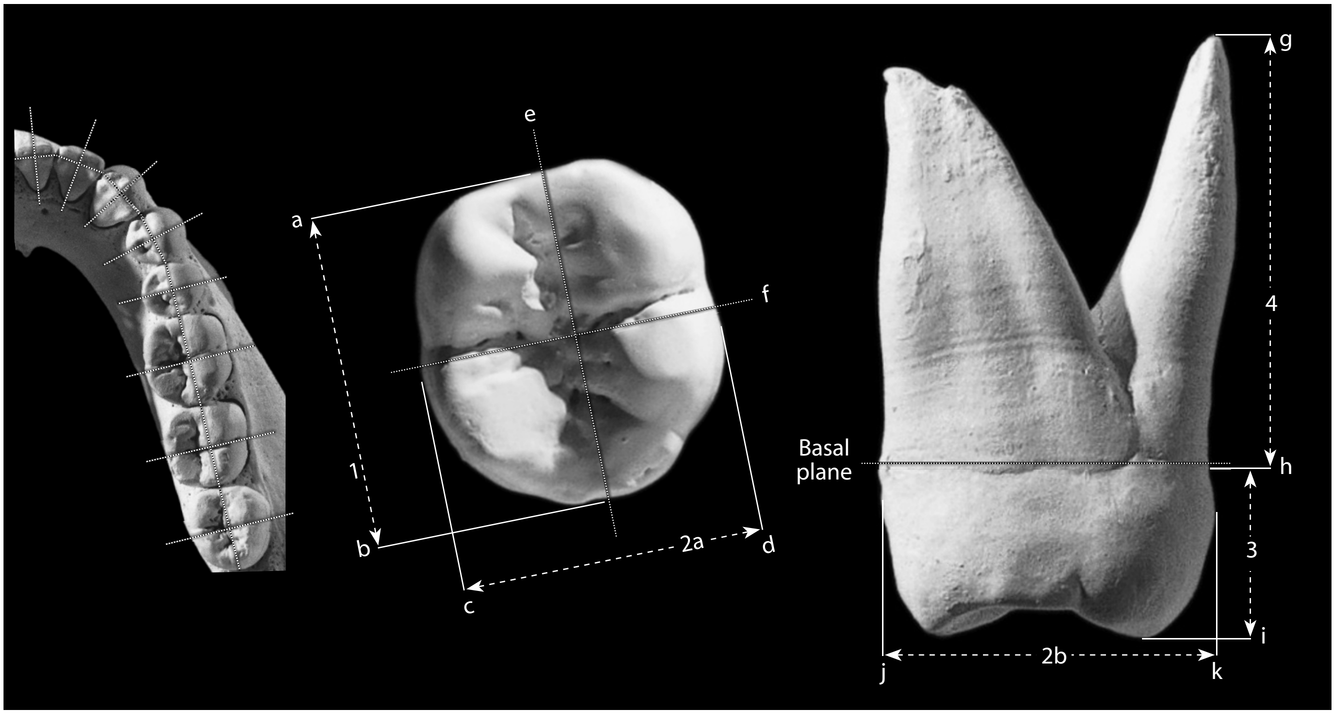


Figure 5.21 **Measurements of teeth**. Note that the mesiodistal axis for each tooth crown must be determined according to its placement in the tooth row (*left*). The labiolingual (or buccolingual) crown axis is then defined as being perpendicular to the mesiodistal axis. Mandibular hemiarcade, natural size; isolated molars, four times natural size.

Locations: a) mesialmost point on mesial surface of crown; b) distalmost point on distal surface of crown; c) lingualmost point on buccal surface of crown; e) buccalmost point on lingual surface of crown; e) mesiodistal crown axis; f) buccolingual crown axis; g) apex of root; h) cervix, cementoenamel line or junction (CEJ); i) apex of lingual cusp (protocone); j) buccalmost point on buccal surface of crown; k) lingualmost point on lingual surface of crown.

Measurements: 1) mesiodistal crown diameter, LM_1; 2a) buccolingual crown diameter, LM_1; 2b) buccolingual crown diameter, RM^2 (taken at widest point along crown height); 3) lingual crown height, RM^2; 4) lingual root length, RM^2.

5.11 Dental Measurements: Odontometrics (Figure 5.21)

Measurements of teeth are used throughout physical anthropology, forensic anthropology, and paleoanthropology in investigations of age, diet, sex, taxonomy, and health. The use of finely pointed steel calipers to measure teeth is a potentially destructive activity, and if the hands are not steadied atop a desk during the operation, movement of caliper relative to tooth surface can result in serious chippage and crushing at the caliper tip. Extreme caution is called for; the caliper is replaceable but the specimen is not.

1. **Mesiodistal crown diameter** (or **length**) (White, 1977: 198; Suwa, 1990: 40–43): Taken with a fine pointed (or dental) sliding caliper held parallel to the crown base (basal plane). This dimension is the absolute length along the mesiodistal crown axis as the tooth typically rests in the dental arcade, normally between the mesial and distal interproximal facets (IPCFs) except for abnormally rotated teeth. It is most accurately measured on erupted but unworn teeth, as interproximal contact facets will cause measurements to be smaller than the actual dimension. Note estimated compensation for IPCF dimensional reduction and do not measure teeth where such estimation is not possible.

2. **Buccolingual crown diameter** (or **breadth**) (White, 1977: 198; Suwa, 1990: 40–43): Taken with a fine pointed (or dental) sliding caliper parallel to the crown base. Is the maximum distance between buccal and lingual crown faces on an axis perpendicular to that of the mesiodistal crown diameter. Avoid including calculus.
3. **Crown height** (White, 1977: 198; Suwa, 1990: 40–43): With a fine pointed (or dental) sliding caliper, measure the vertical distance from the cementoenamel junction (CEJ) to the unworn apex (reconstructing for wear, if necessary) of the highest adjacent crown. Be sure to specify the region of the molar or premolar crown for which the height is being measured (*e.g.,* mesiobuccal crown height); incisor and canine crown heights are taken from the incisal margin to the labial line, along the central crown axis.
4. **Root length** (Garn et al., 1978: 636): With a fine pointed (or dental) sliding caliper, measure the vertical distance from the cementoenamel junction (CEJ) to the root apex (avoid resorbed or incomplete roots). Be sure to specify the root for which the length is being measured (*e.g.,* lingual root length).

5.12 Dental Nonmetric Traits

Nonmetric traits of the teeth are a staple of dental anthropology. Whereas many of these variants have been called out in the preceding descriptive sections, there are dozens more that can be found in Hanihara (2008), Hillson (1996), and Scott and Turner (1988, 1997).

Suggested Further Readings

Because they are central to so many studies, an enormous literature on teeth has developed over several centuries (see, for example, Metress and Conway, 1974, for a partial bibliography through 1974, and Foley and Cruwys, 1986; Scott and Turner, 1988; Kelly and Larsen, 1991; Hillson, 1996; and Alt et al., 2003, for more recent reviews). Anthropologists, paleontologists, forensic analysts, and dental researchers all continue to contribute to this literature. *Dental Anthropology,* a publication of the Dental Anthropology Association, is a newsletter/journal with articles, reviews, and regular bibliographies.

Alt, K. W., Rösing, F. W., and Teschler-Nicola, M. (Eds.) (2003) *Dental anthropology: Fundamentals, limits and prospects.* New York, NY: Springer. 564 pp.
An introduction to, and survey of, research in dental anthropology.

Avery, J. K. (Ed.) (2001) *Oral development and histology* (3rd ed.). New York, NY: Thieme. 480 pp.
A comprehensive textbook on oral anatomy.

Hillson, S. (1996) *Dental anthropology.* Cambridge, UK: Cambridge University Press. 373 pp.
Everything about teeth, from an anthropological perspective.

Hillson, S. (2005) *Teeth* (2nd ed.). Cambridge, UK: Cambridge University Press. 388 pp.
An excellent guide to all matters having to do with teeth. Fine illustrations of a variety of mammalian teeth and a full consideration of human teeth from many perspectives.

Irish, J. D. and Nelson, G. C. (Eds.) (2008) *Technique and application in dental anthropology.* Cambridge, UK: Cambridge University Press. 470 pp.
This edited volume focuses on methodological aspects of dental anthropology, discussing a variety of techniques useful in the study of teeth.

Kelley, M. A., and Larsen, C. S. (Eds.) (1991) *Advances in dental anthropology.* New York, NY: Wiley-Liss. 389 pp.

An edited volume covering the spectrum of dental anthropology.

Kieser, J. A. (2008) *Human adult odontometrics: The study of variation in adult tooth size.* Cambridge, UK: Cambridge University Press. 208 pp.

A comprehensive guide to dental measurements and metric variation in human teeth.

Nelson, S. J. (2009) *Wheeler's dental anatomy, physiology and occlusion* (9th ed.). St. Louis, MO: Saunders/Elsevier. 368 pp. + CD-ROM.

Considered the standard reference work for dentistry, this well-illustrated volume has useful chapters on deciduous teeth, dental eruption, and occlusion, as well as 7 chapters dedicated to the morphology of specific categories of teeth.

Scheid, R. C. (2007) *Woelfel's dental anatomy: Its relevance to dentistry* (7th ed.). Baltimore, MD: Lippincott Williams and Wilkens. 534 pp.

Everything about teeth, from the dentist's perspective. Excellent illustrations of variation among many individuals for each tooth.

Scott, G. R., and Turner, C. G. (1997) *The anthropology of modern human teeth: Dental morphology and its variation in recent human populations.* New York, NY: Cambridge University Press. 382 pp.

A comprehensive guide to the anthropological utility of dental variation in modern humans.

Steele, D. G., and Bramblett, C. A. (1988) *The anatomy and biology of the human skeleton*. College Station, TX: Texas A&M University Press. 291 pp.

A good atlas with labeled photographs and written descriptions of human teeth.

Taylor, R. M. S. (1978) *Variation in morphology of teeth: Anthropologic and forensic aspects.* Springfield, IL: C. C. Thomas. 384 pp.

An eye-opening guide to variation in human dental anatomy.

Van Beek, G. C. (1983) *Dental morphology: An illustrated guide* (2nd ed.). Woburn, MA: Butterworth-Heinemann. 144 pp.

A good introduction to dental morphology, with large, labeled illustrations of each tooth and a handy glossary of specialized terms.